Space Technology Research Grants

Strain Sensors Based on Sandwich Structures of Crumpled Graphene for Structural Health Monitoring

Completed Technology Project (2016 - 2020)

Project Introduction

Space based systems are subject to varied stresses which induce damage leading to failure, therefore it is necessary to develop an onboard system to monitor structural health. The primary components of these systems are compact flexible strain gauges that can be applied to arbitrary structures. Researches have depended on nanomaterials to develop these systems, the most promising of which is graphene, a single atom thick layer of carbon that exhibits excellent mechanical and electrical properties, which has been successfully used in strain sensors, but requires advancement in sensitivity and ease of integration to be useful. Herein is proposed a stacked biaxially textured graphene strain sensor (SBTGRP) for structural health monitoring which takes advantage of the interaction between two mating sheets of textured graphene when subject to strain to measure changes to a system. Crumpled graphene consists of graphene which has been deformed to adopt a crumpled surface; this unique topography offers several advantages in developing strain sensors, most obviously increased conformability. The most interesting possibility for strain sensing is based on the interaction of two layers of textured graphene. Two mating crumpled graphene sheets make contact at the tips of the corrugations on their surfaces, these points of contact serve as electrical connections and the prevalence of these contacts can be gauged by measuring the electrical resistance between the two layers. If this stacked system is stretched the crumpled graphene will begin to adopt a flatter configuration and the height of the corrugations will decrease, reducing the number of contact points, increasing the resistance, and allowing for determination of the strain on the system. We have already developed SBTGRPs for human body motion monitoring but they remain to be optimized for use in structural health monitoring. Development of these sensors will allow for the creation of an integrated health monitoring system which will improve the reliability of future missions by offering a method for life assessment. The main goals in optimizing SBTGRPs are: perfecting their fabrication method, quantifying their response to various modes of forcing, increasing their sensitivity to the low amplitude strains of interest for structural health monitoring, and integrating multiple strain sensors into an array to achieve full multimodal deformation sensing. While current strain sensors are tested in response to normal strains, in real world applications the systems will be subject to multiple modes of forcing, therefore it is necessary to fully characterize sensor behavior, using tension and torsional testing stages, under these conditions. This series of tests will allow for determination of unique sensor behavior which may be used to differentiate between types of strain as well as gauge their reliability. More importantly, the quality of sensing is dictated by the conditions at the interface, therefore sensitivity could be increased via careful control of the interface characteristics between the two crumpled graphene layers. Of primary interest is determining how the initial degree of crumpling of the upper and lower graphene layers affects sensitivity. A high degree of initial crumpling leads to a large number of interlayer contacts and therefore will require significantly more stretching to

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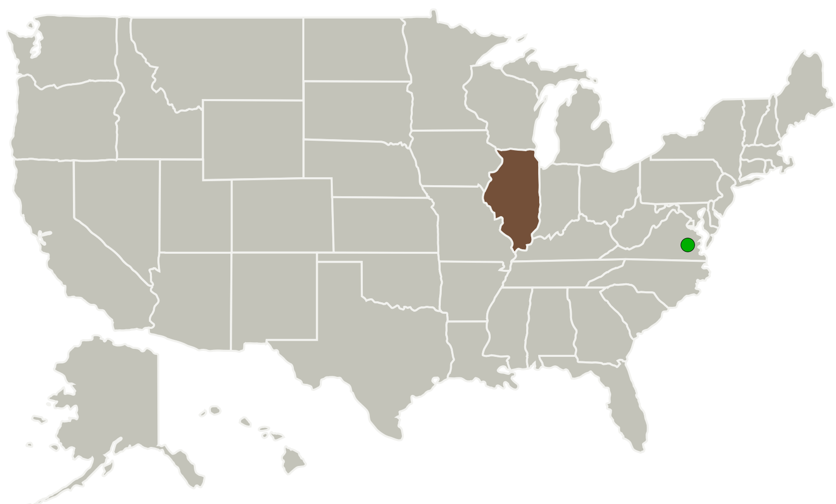
generate a significant number of disconnections therefore reducing sensitivity to low strains. Therefore it may be possible to increase sensitivity by reducing the degree of initial crumpling. As a final goal the realized sensors will be integrated into a large scale array for detailed structural health monitoring. Access to NASA facilities, for instance the advanced mechanical testing labs available at the Goddard Spaceflight Center, and researchers would be invaluable in advancing this work to develop devices to improve the reliability of space based systems.

Anticipated Benefits

Development of these sensors will allow for the creation of an integrated health monitoring system which will improve the reliability of future missions by offering a method for life assessment.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Illinois at Urbana-Champaign	Lead Organization	Academia	Urbana, Illinois
Langley Research Center(LaRC)	Supporting Organization	NASA Center	Hampton, Virginia

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Illinois at Urbana-Champaign

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Sungwoo Nam

Co-Investigator:

Peter M Snapp

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Primary U.S. Work Locations

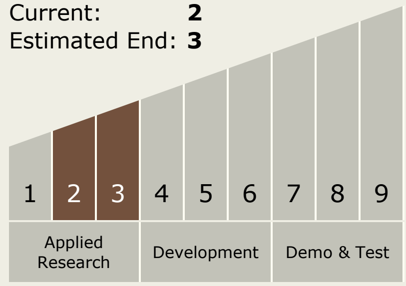
Illinois

Project Website:

https://www.nasa.gov/strg#.VQb6T0jJzyE

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  └─ TX12.3 Mechanical Systems
    └─ TX12.3.4 Reliability, Life Assessment, and Health Monitoring